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BGO In Several Satellite-Borne Applications

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Abstract

An experiment is being prepared to be flown on a NASA/NOAA TIROS satellite. Named DOEE-1 (Department of Energy Experiment), it will carry a segmented 2.7" x 3" BGO (Bismuth Germanate) scintillator. Sufficient telemetry will be provided to evaluate the performance exhaustively during a long exposure in space. Another instrument including a BGO scintillator, named SEE (Spectrometer for Energetic Electrons), has been operating at synchronous altitude since 1979, providing measurements of electron fluxes at $2.5 < E < 9$ meV. Unfortunately, the data are not suitable for a critical evaluation of the BGO scintillator performance, since scintillator response is not directly monitored.

Introduction

Los Alamos maintains an interest in detecting nuclear gamma radiation ($E \approx 1$ MeV) in space. Presently, scintillation detectors are the most effective instrument in this application, providing high sensitivity and long-term reliability coupled with reasonably good resolution. Bismuth germanate (BGO) is especially promising for the detection of gamma radiation at energies of 1 MeV and greater.

The DOEE-1 Experiment

In order to evaluate the performance of BGO in a long-duration exposure to a space environment, a developmental instrument, named DOEE-1 (Department of Energy Experiment), is being prepared to be flown on a NASA/NOAA TIROS satellite. The TIROS orbit will provide periodic exposure to high energy electrons (in the polar horns of the radiation belt) and to high-energy protons (in the South Atlantic anomaly). The instrument is to replace an existing TIROS instrument, thus the design is limited by the constraints (configuration, weight, and telemetry resources) imposed by the previously defined interface requirements. A photograph of partially completed BGD (Bismuth Germanate Detector) sensor assembly is shown (with covers removed) as figure 1.

The sensor is based upon a right-circular cyclinder of BGO 2.7" diameter x 3.0" length. The cylinder is formed of four elements generated by dividing each of two 1.5" thick discs into two "D" shaped segments. The ends of the cylinder are beveled to facilitate supporting the assembly. A hole is bored through the center of and transverse to the axis of the cylinder and (at the intersection between the discs) to accept a small energetic-particle detector, and each element is machined on the cylindric surface so as to accept the spherical window of an RCA type C70132 photomultiplier tube. A plastic model of the BGO scintillator assembly is shown in figure 2.

An 'exploded" view of the components that make up the sensor is shown in figure 3. The BGO scintillator assembly is positioned and supported within the housing between a pair of beveled plastic retainers, held by a compression preload exerted by the screw-in cover. A transparent silicone pad will provide a resilient coupling between the individual scintillator elements and the photomultiplier (PM) tubes. The base of each PM and the associated bleeder circuit are supported by a two-piece molded collar which also is utilized to transmit a compressive force holding the PM firmly against the scintillator. The conventional end-window PM tube in the left foreground is included only to illustrate an example of the thick-film hybrid bleeder to be employed. The small cylindrical housing is to contain a 3/4" PM tube and plastic scintillator to be used to monitor the charged particle environment in which the instrument is operating.

The charged particle monitor is intended to monitor the environment which may contribute to the response in the primary (BGO) sensor. These data will also be used to automatically disable the BGO sensors (by removing the high-voltage) during passages through the most intense region of the South Atlantic anomaly. Furthermore, the particle monitor has been buried between the BGO elements in order to allow identification of positrons, by establishing coincident detection of one or both of the 0.5 meV annihilation gamma rays by the BGO sensors. This will extend a positron survey to regions of the magnetosphere not sampled by similar instruments on OGO-1 and OGO-3 (Cline and Hones, 1968).

The analog electronics are to be stacked on bosses provided on the photomultiplier housings, and also within the cavity remaining within the box forming the base of the sensor housing, shown in figure 4. The five compartmented enclosures shown mounted in this box will house the five steppable (5-bit or 32-level) high-voltage supplies powering the photomultiplier tubes. Logical electronics and a magnetic bubble memory are to be housed separately, in the DPM (Data Processing Module) internally mounded within the spacecraft.

A block diagram of the analog electronics is shown in figure 5. Each of the four BGO sensors will be served by identical electronics, including a preamplifier, amplifier, and a 5-bit (32-level) linear A/D converter. It is intended that this channel span the range $40 < E < 700$ keV, with provision for raising the threshold to 100 keV by command. Higher level signals, derived from the four individual preamps, are added in a summing amplifier and analyzed by a single 7-bit (128-level) nonlinear A/D converter. This was felt to be desirable because responses at higher energies will be often distributed between several of the elements. This channel will cover a range $0.6 < E < 20$ meV.

The charged-particle detector response is analyzed by a 4 bit (16 level) A/D channel. Two additional bits of information included with each analysis indicate whether none, one, two, or more BGO sensors responded in coincidence within an energy window around 0.5 MeV. This window interval is defined by a hybrid analog/logical circuit for both technical and practical reasons.

The results of the analyses performed on the outputs of the individual sensors are assembled in a shift register (FIFO, first-in/first-out) to be transmitted to the logical electronics and memory. A block diagram of the system is shown in figure 6. The dashed line indicates the division of the circuitry between the BGD and DPM. The logical functions of data handling are largely performed by a microprocessor, and are not readily described by a block diagram. Data input to the logics, however, is provided by a direct-memory-access (DMA) unit.

The microprocessor functions are programmed through software stored in a programmable read-only memory PROM. It provides for real-time data handling, formatting for the telemetry a full set of spectral data on a 64 s period. It also identifies rapidly-rising transient events, storing high-resolution records of these events in the bubble memory (with a capacity of a half-million bits). Upon termination of an event record, these stored high-resolution data are formatted for telemetry, replacing the real-time data. Configuration commands are processed by the microprocessor, then loaded into dedicated registers in both the DPM and the BGD. State-of-health functions are presented upon dedicated lines through the DPM at the spacecraft interface. The microprocessor also performs logical tests of the bubble memory and the RAM, and a statistical test of sensor response. The results of these tests are presented as a part of the digital status information.

This instrument is being prepared on a schedule which will allow delivery in early June 1983. The schedule for spacecraft testing provides for a launch in 1985. This schedule is, however, tentative and may be either accelerated or retarded depending upon program requirements.

The Spectrometer for Energetic Electrons (SEE)

An instrument employing a BGO scintillator is currently operating at synchronous orbit. This instrument is an electron spectrometer monitoring electrons in the energy range 2.5 < E < 9 MeV. A plan view of the instrument is shown in figure 7. The spectrometer is based upon a BGO scintillator, in which the energetic electrons are absorbed. BGO was chosen as the scintillator because it allowed a compact design, necessary to accommodate the instrument as a direct replacement for one of a different type, without modifying either the mechanical or electrical interface.

The scintillator is shielded (by a thick aluminum case and a glass lightpipe) from direct penetration of electrons to 15 MeV. A collimated entrance aperture is defined by tantalum and copper elements. Electrons entering through the collimator are identified by the response they produce in a silicon solid-state detector (2 element) immediately in front of the scintillator. Electrons within the range of the measurement are minimum-ionizing particles, and thus deposit a uniform energy in the silicon detectors. Other minimum-ionizing particles usually are rejected because they deposit excessive energy in the scintillator.

Data from the scintillation spectrometer is analyzed in only four differential intervals (because of telemetry limitations), between nominal levels of 2.5, 4, 6, 9, and 15 MeV. The analysis is performed only when coincident response in the silicon detector is observed. The silicon detector counts in the "window" energy interval are also telemetered. Unfortunately, these data do not allow a critical evaluation of the performance of BGO in this environment because response in the scintillator is not monitored independently of response in the silicon detector.

The capability to measure high-energy electrons was developed because of a concern that the then-current AE-4 model of the energetic electron population at synchronous altitude did not adequately describe the contribution of electrons at energies greater than 2 MeV. These higher energy electrons are of importance to spacecraft operating in this regime since they could produce:

1) Cable charging and deep dielectric charging.
2) Logics upsets and anomalies.
3) Dose effects from the penetrating electrons which are difficult to shield against.

The first instrument of this type was placed in synchronous orbit in 1979, and monitoring has been provided nearly continuously since that time. Preliminary data from the instrument have been reported (Klebesadel et al. 1982) and have been published as a part of a synoptic data set which includes analyses of lower-energy electrons and protons (Baker et al. 1982).

During this extended period of operation, a number of periods of unusual activity have been observed. Spectral distributions of the energetic electrons during the first of these, occurring in June 1980, is shown in figure 8. These spectra represent daily averages, as indicated. Also shown is the AE-4 model spectrum, which is seen to be deficient at higher energies as compared to these measurements. Of course, these data are unusual, and not representative of average conditions.

These times of unusual activity appear to be periodic, occurring at intervals of about 13 months. There is some evidence that these correspond to times when the sun's twisted magnetic field connects the earth and the planet Jupiter, as shown in figure 9. Electrons emitted from the Jovian magnetosphere may then be confined by the solar magnetic field and ducted to the vicinity of the earth. Such a mechanism was first suggested by Teegarden et al. (1974).

Conclusions

Although BGO has already been employed successfully in an application in space, the performance of that BGO spectrometer can not be critically evaluated based upon the data which are available. The DOEE-1 instrument being prepared to be flown aboard a TIROS satellite will provide a comprehensive analysis of the performance of a BGO spectrometer. This satellite will be placed into an orbit which will subject the instrument to a long-duration exposure to a wide range of radiation environments. Thus, data returned from this instrument will be useful in assessing the suitability of BGO in other anticipated satellite-borne applications.

References

Baker, D. N., Higbie, P. R., Belian, R. D., Hones, E. W., and Klebesadel, R. W., The Los Alamos Synchronous Orbit Data Set, . . .

Cline, T. L., and Hones, E. W., Search for Low-Energy Interplanetary Positrons, Canadian Journal of Physics, 46, p. S527, 1968.

Klebesadel, R. W., Baker, D. N., Higbie, P. R., and Belian, R. D., Very High Energy Electrons in the Outer Magnetosphere (Abstract) EOS, 62-45, p. 993, 1981.

Teegarden, B. J., McDonald, F. B., Trainor, J. H., Webber, W. R., and Roelof, E. C., Interplanetary MeV Electrons of Jovian Origin, J. Geophys. Res., 79-25, p. 3615, 1974.

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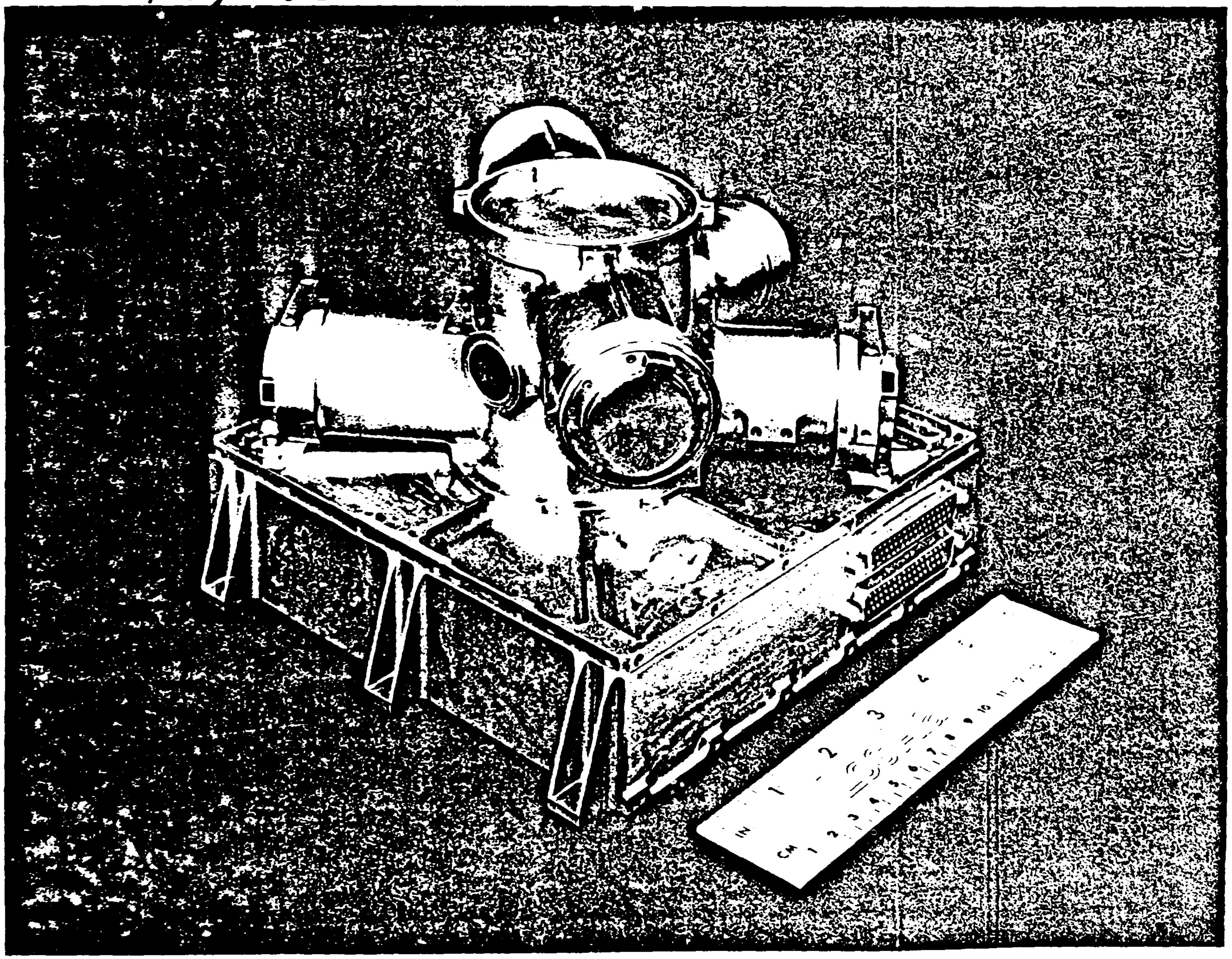

Figure 1

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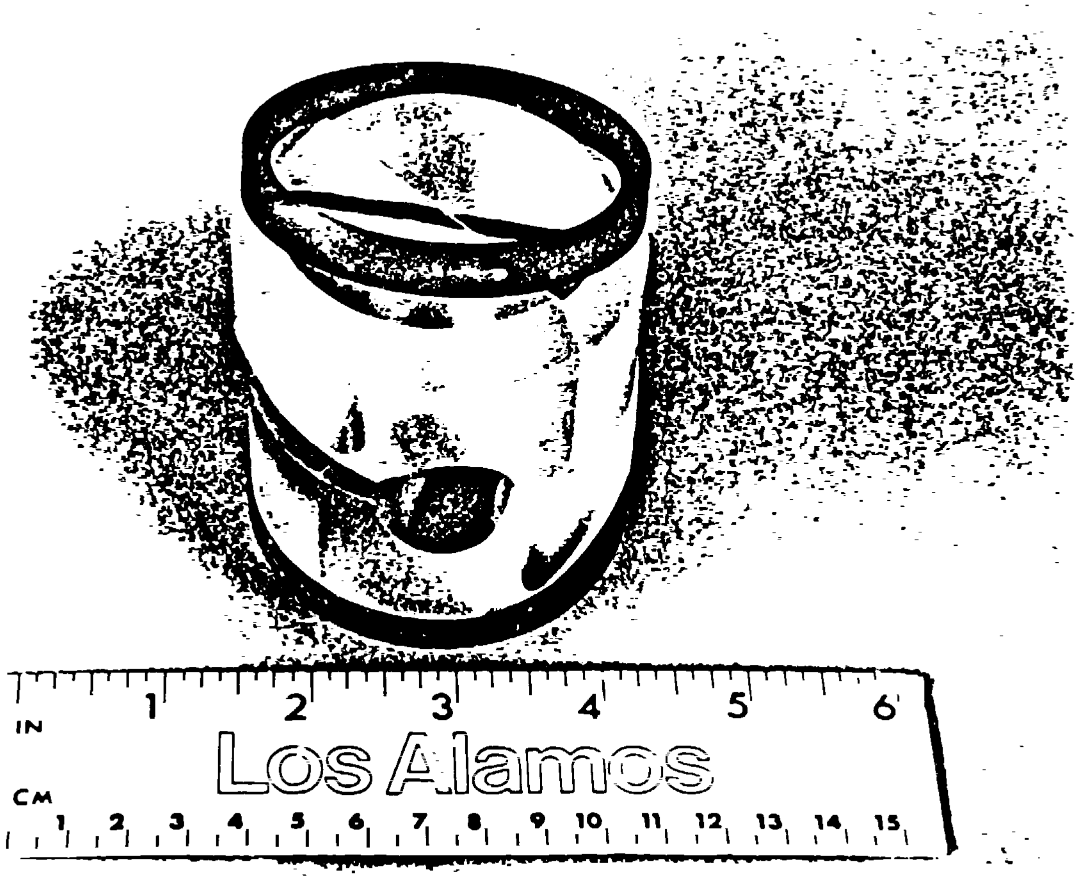

Figure 2

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Figure 3

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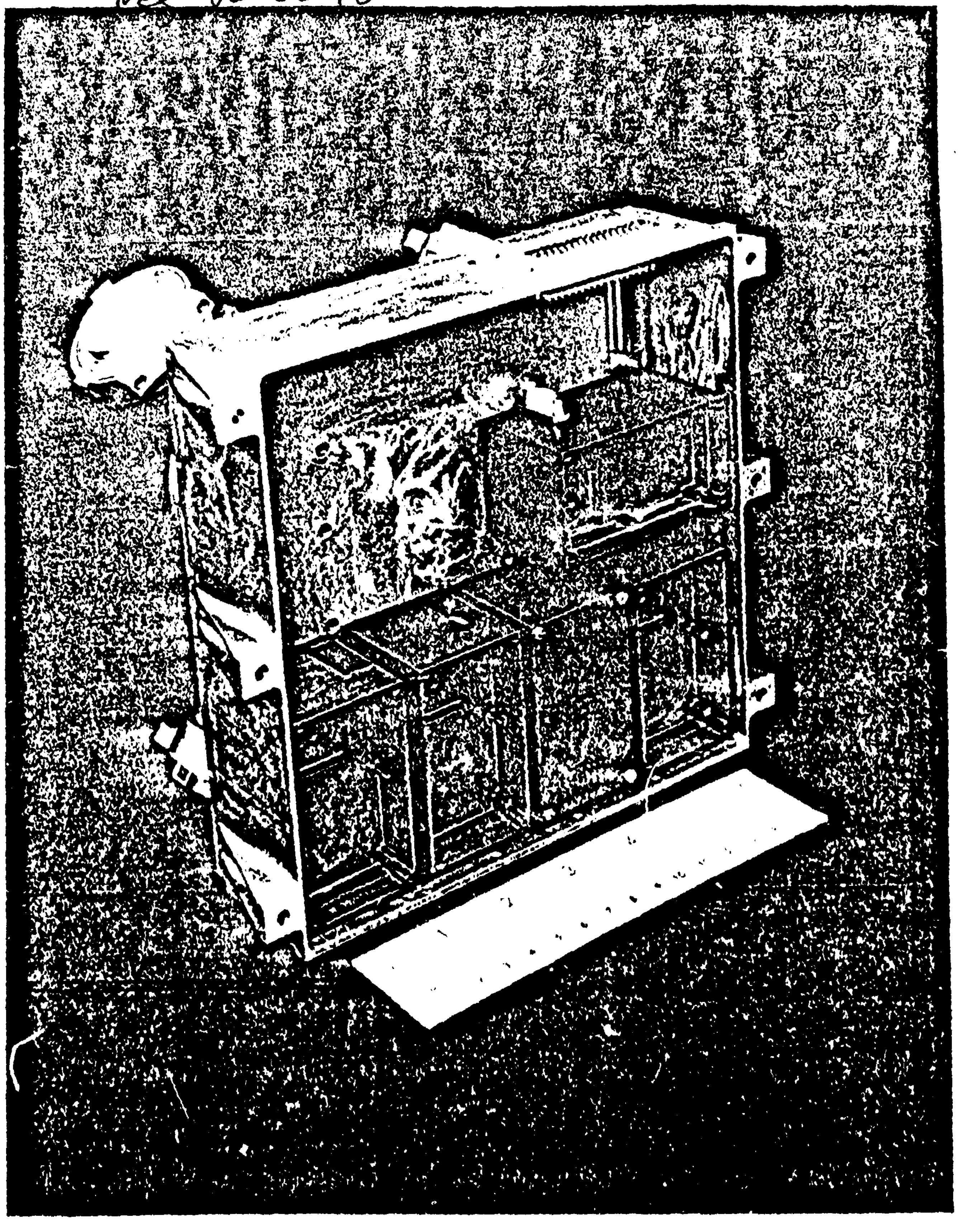
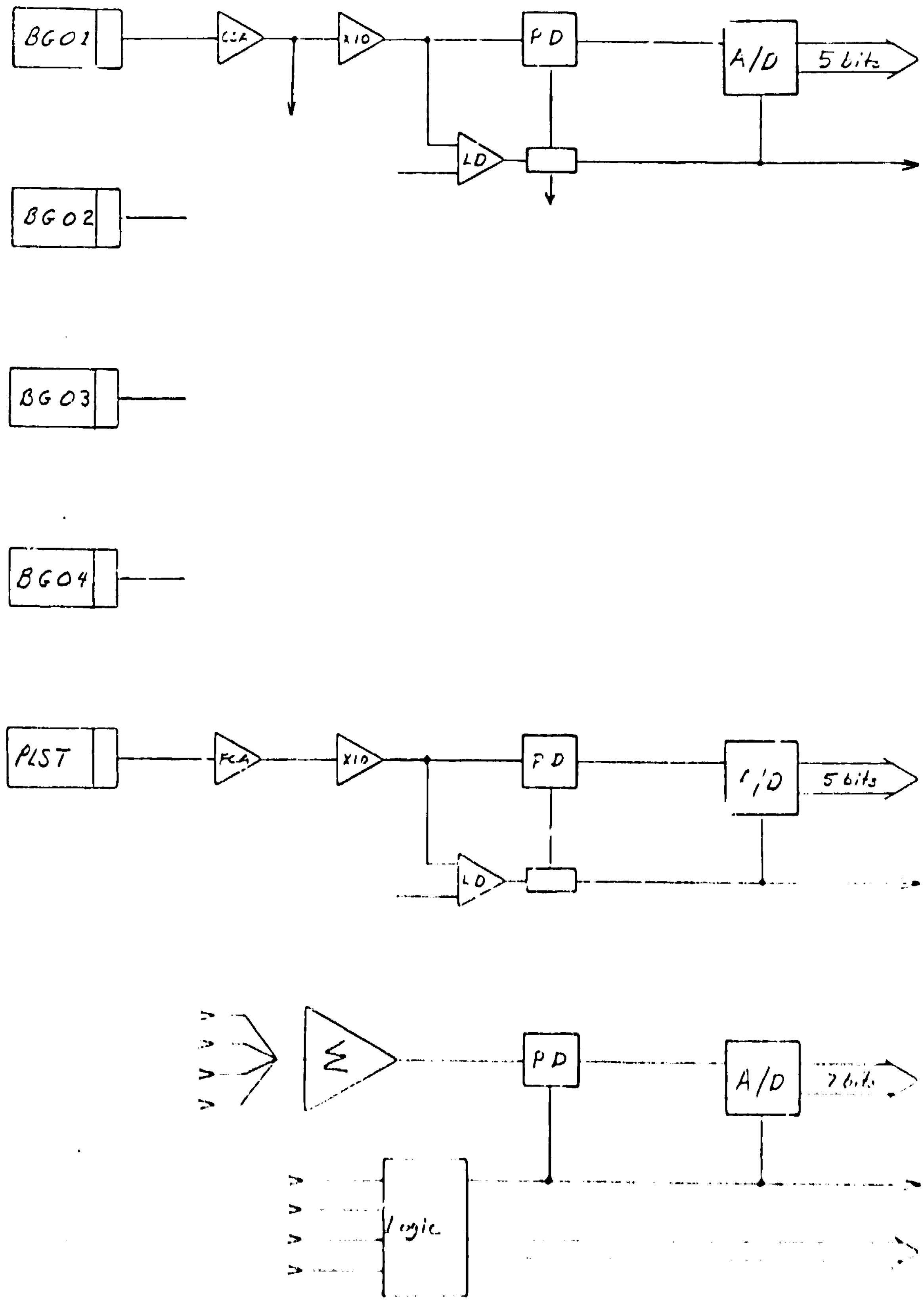


Figure 4

E-2 drawing replaces.



ANALOG ELECTRONICS

Figure 5

PLOCK DIAGRAM OF DOEE EXPERIMENT

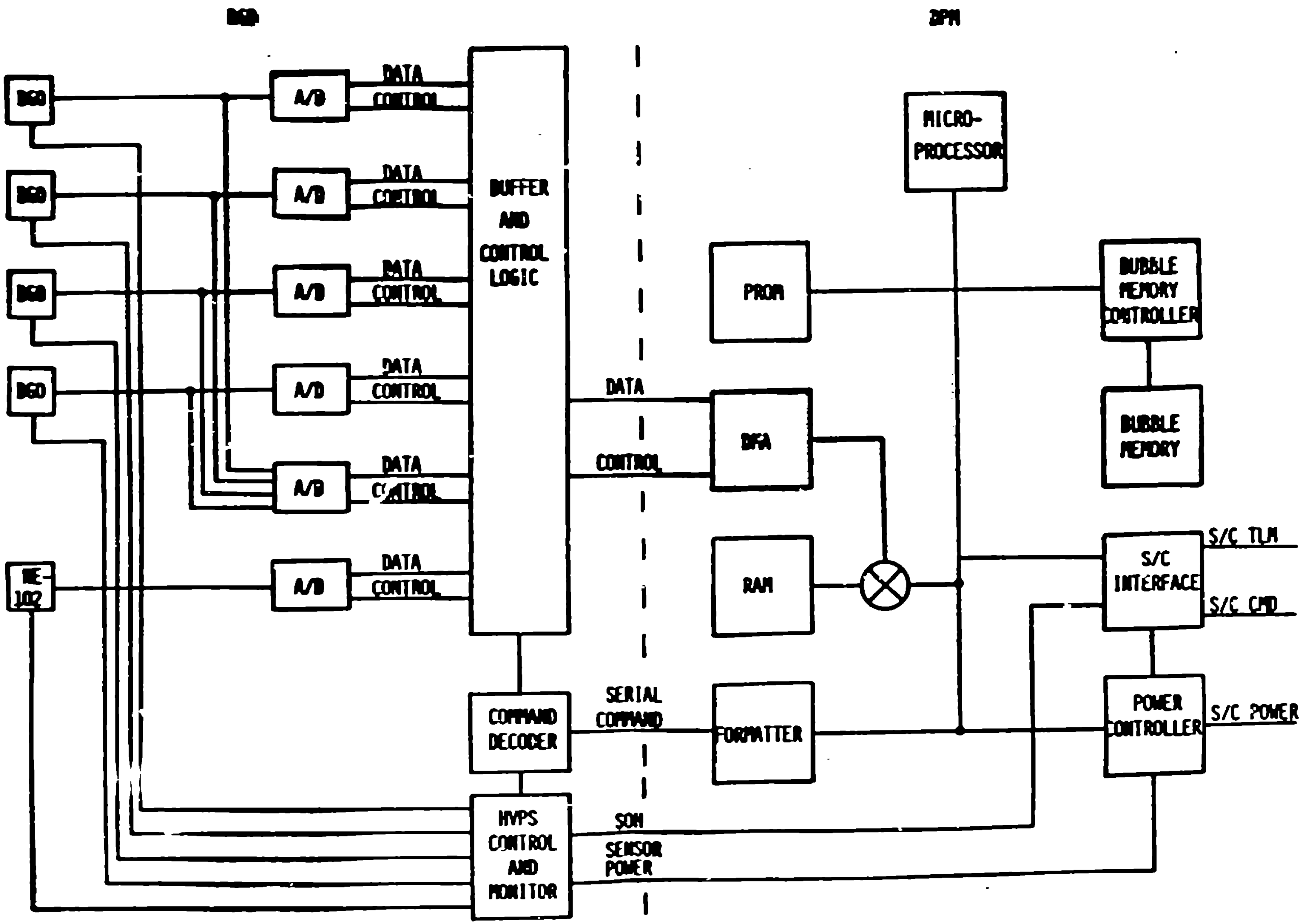


Figure 6

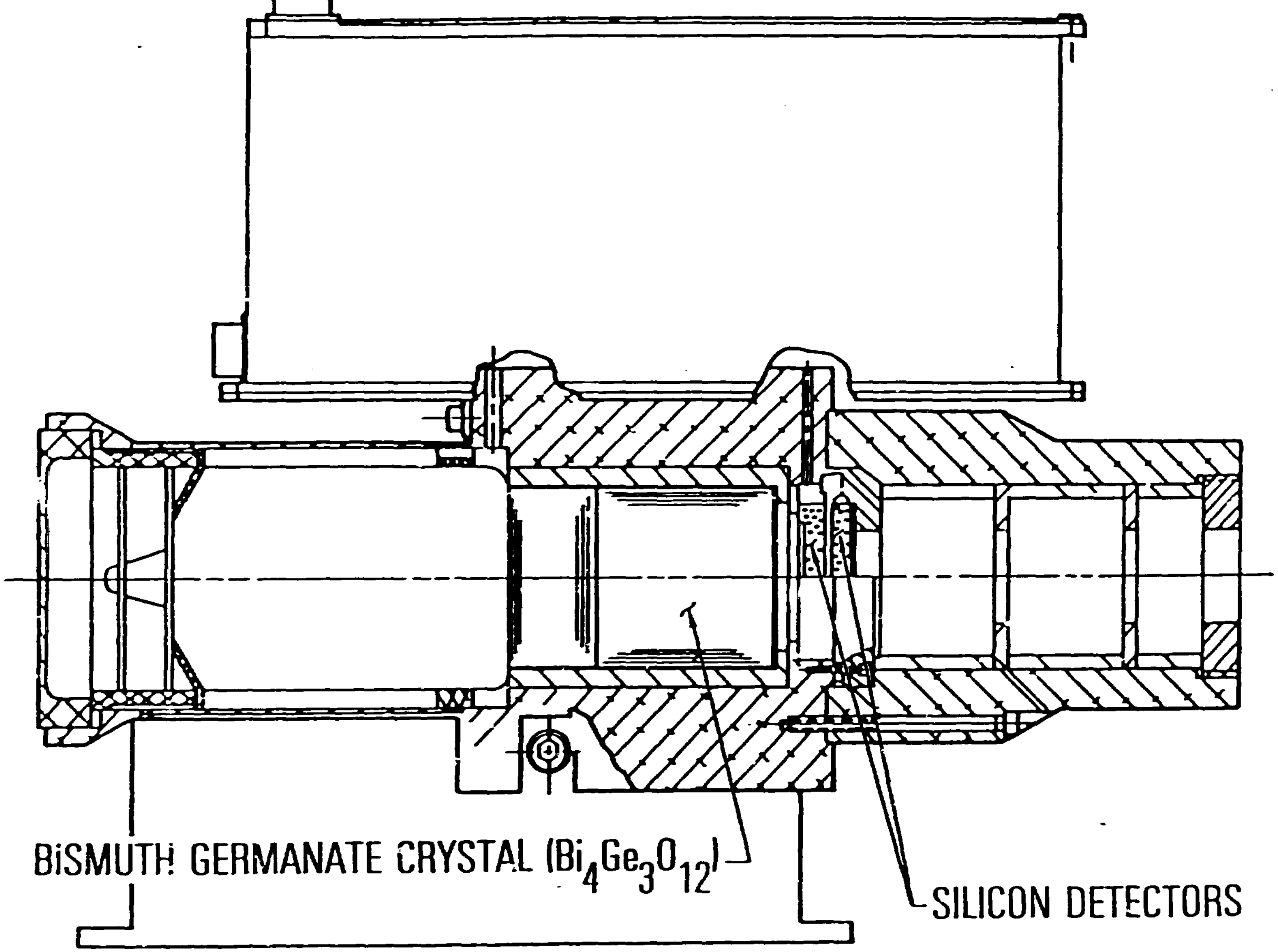


Figure 7

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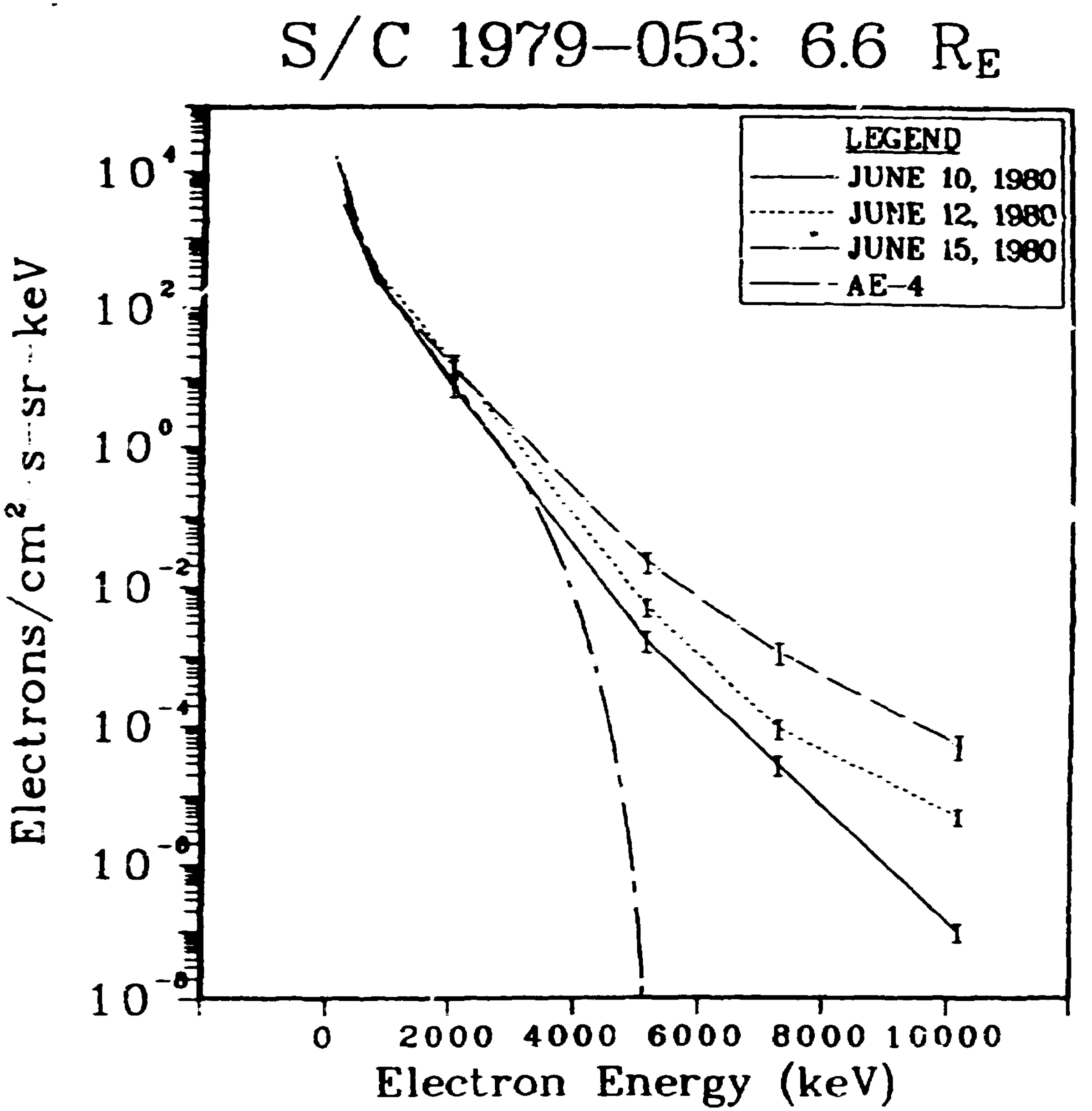

Figure 8

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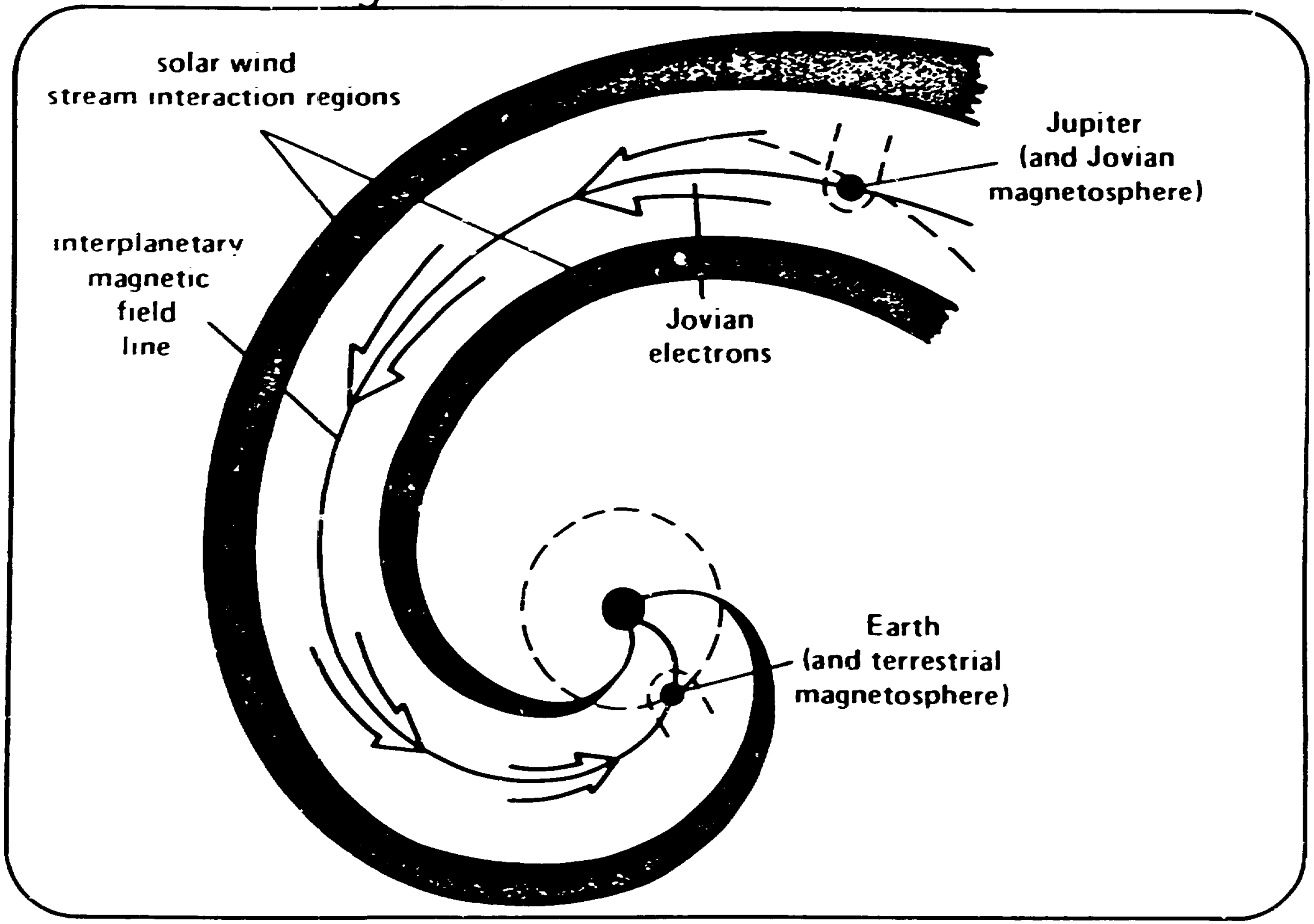

Figure 9

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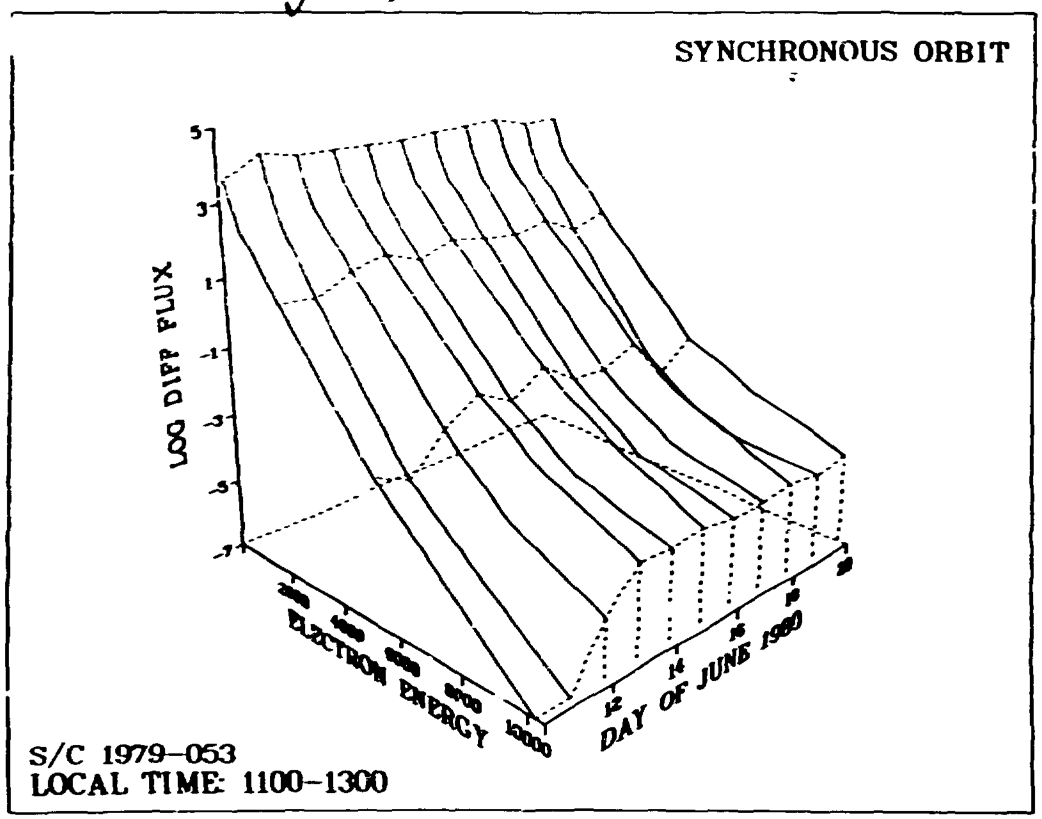

SYNCHRONOUS ORBIT
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